

Mitigation benchmarks from the 2025 community update of global emissions pathways

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Abstract

Long-term global emissions scenarios underpin climate policy by providing quantitative benchmarks for near-term actions consistent with long-term temperature goals. However, scenario benchmarks can quickly become outdated as real-world emissions, policies, technologies and even geopolitics evolve. Here we present an updated and curated ensemble of global integrated assessment model (IAM) scenarios developed since the IPCC Sixth Assessment Report. We use a continuous “live” collection and vetting framework designed for regular updating - with planned annual releases - to derive up-to-date policy-relevant benchmarks. Of more than 1,500 collected scenarios, only a minority remains consistent with recent trends between 2015 and 2025. After assessing feasibility, plausibility, and sustainability, 162 scenarios form the basis for updated benchmarks. These indicate that pathways limiting peak warming to around 1.7 °C above pre-industrial levels represent the lowest warming outcomes currently supported in the recent literature, requiring global greenhouse gas (GHG) emissions reductions of around 60% by 2035 and 90% by 2050 relative to 2019, with net-zero CO₂ emissions reached around 2050. All Paris-consistent benchmarks require a rapid transitioning away from unabated fossil fuels, an unprecedented scale-up of renewable energy, and limited but necessary deployment of carbon dioxide removal (CDR). While limiting peak warming to 1.5 °C with low or no overshoot is no longer feasible, returning warming to 1.5 °C this century (after overshooting to about 1.7 °C) remains possible.

Introduction

Long-term global emissions scenarios are a key analytical tool for assessing the scale and timing of system transitions required to meet specific global warming targets. As such, they play a central role in informing decision makers and in defining near-term policy benchmarks that are consistent with long-term climate goals ^{1–6}.

A given climate outcome can be achieved through a wide range of alternative pathways, reflecting different assumptions about socio-economic development, technology deployment, policy design, and behavioral change. To understand which characteristics of low-carbon transformations are robust across the board and which rely on specific societal preferences or choices, large scenario ensembles have been collected and analyzed ^{7–9}. The purpose of such ensembles is not to forecast future trends, but rather to explore different options and understand possible consequences of distinct policy decisions ^{10–12}.

In the recent past, scenario ensembles have been compiled in support of successive scientific assessments of the Intergovernmental Panel on Climate Change (IPCC) ^{7,13–15}, where they underpinned key conclusions that provided quantitative benchmarks taken up in international climate negotiations ^{6,16}. These benchmarks show, for example, how much global emissions would need to fall by 2030, and when global CO₂ emissions would need to reach net zero, to limit warming to specific temperature levels.

However, the questions that emissions scenarios can credibly inform change over time. When real-world emissions trajectories, energy and land-use system dynamics, policy environments, and technological developments diverge from the assumptions embedded in earlier scenarios, those scenarios cease to be fit for informing current and near-term target setting. Their outputs should therefore no longer be used as contemporary benchmarks. Ganti et al.¹⁷ underscores this point, arguing that as the world moves into an overshoot context, scientific and policy frameworks - including scenario-based assessments - must adapt to remain relevant. Earlier scenarios nevertheless remain valuable as records of pathways that were once considered feasible but were ultimately not pursued.

A continuous and systematic process of scenario collection and curation is therefore essential. Such a process enables the incorporation of new scenarios that reflect the most recent scientific and socio-economic developments, while also identifying scenarios that are no longer consistent with observed trends and that therefore will start to serve a more retrospective role in policy analysis.

In response to this need, the Scenario Compass Initiative (SCI) was established as a community-driven framework to continuously collect, curate, and assess global emissions scenarios. SCI provides both a technical infrastructure and a governance structure that enables regular updating of scenario ensembles, transparent vetting against real-world developments, and early access to new scenarios for scientific and policy analysis.

The scenario collection builds on the most recent global scenario ensemble compiled for the IPCC Sixth Assessment^{5,7}, which comprised more than 1,200 global emissions pathways. Extending this foundation, we collected more than 350 new integrated assessment model (IAM) scenarios developed since AR6, resulting in a substantially expanded and updated ensemble that reflects recent advances in modeling, data, and policy context (for an overview of the scenarios see Supplementary Information, Table SI.6).

We apply a set of basic vetting criteria to remove scenarios whose assumptions and projected trends have become inconsistent with recent observations. These criteria (see Supplementary Information, Table SI.1) evaluate the extent to which near-term emissions, energy, and land-use trends of the scenarios have diverged from real-world observations in ways that affect the usefulness of the results. Scenarios that do not meet these criteria are archived and remain accessible for users, but are excluded from the ensemble from which we derive the benchmarks (see Figure 1, panel b).

In addition to the initial vetting step, we assess the feasibility and sustainability of scenario trends. Together, these assessments identify scenarios that do not raise major concerns along these dimensions. This step is critical, as it responds to long-standing critiques of mitigation scenarios that rely heavily on unconstrained or indiscriminate deployment of technologies^{18–20,5}. It ensures that benchmark identification builds on a scenario space that is both consistent with plausible technology deployment and aligned with societal priorities^{21,22}.

The feasibility assessment evaluates the pace of near-term technological deployment to 2030, with particular attention to renewables and other emerging technologies, including carbon capture and storage (CCS, see Section 1.2 of the Supplementary Information). This assessment is most relevant for stringent mitigation pathways, which require rapid transitions and scale-up to meet the climate goals. For high-emissions pathways, it instead serves as a plausibility check, ensuring that assumed trends do not fall below minimum deployment expectations, for example, where technology uptake would be inconsistent with projects already under development or with policies currently in place. We broadly follow the technology validation approach of Weigmann et al.²³, which draws on evidence from the historical diffusion of successful technologies and near-term deployment expectations to derive minimum and maximum build-out rates defining a plausibility window to 2030.

The sustainability assessment considers three key dimensions: the sustainable use of bioenergy¹⁹, implications for food security^{24,25}, and the long-term sustainability of global CO₂ storage volumes of both fossil and non-fossil carbon capture and storage options²⁶.

Many scenarios assessed previously have become outdated

Of the 1,595 scenarios collected, 347 meet the basic vetting criteria (11 scenarios were excluded due to incomplete variable reporting; see Methods). This substantial reduction does not imply that the excluded scenarios were erroneous, but rather that real-world developments have followed pathways that diverge from the assumptions on which many scenarios were built. In particular, scenarios assuming very rapid and early emissions reductions are disproportionately affected, reflecting policy and investment choices that did not materialize. At the same time, higher-emission scenarios are also excluded where they fail to capture recent deployment trends of emerging technologies (Figure 1, panels a, b, c, and e).

Among the 347 vetted scenarios, the majority (330 scenarios) do not raise major sustainability concerns. However, many exhibit near-term plausibility or feasibility concerns related to technology deployment rates for, e.g., CCS and nuclear (Figure 1, panels b and c). In addition, a subset of scenarios proves overly pessimistic with respect to recent solar and wind deployment trends (see Supplementary Information, Table SI.2). After applying all assessment steps, 162 scenarios remain that do not raise major sustainability, feasibility, or plausibility concerns under the framework applied here. We use this subset as the basis for assessing updated global emissions benchmarks.

AR6 pathways limiting warming to “1.5°C with low or no overshoot” are no longer feasible

To facilitate a systematic assessment, emissions scenarios are grouped into categories corresponding to different levels of future global warming. The most recent IPCC assessment⁴ distinguished eight categories ranging from very low future warming levels (*C1: limiting warming to 1.5°C with low or no overshoot*) to high warming levels (*C8: warming of >3.5°C*).

Applying this categorization to the updated scenario ensemble reveals substantial shifts in the availability of scenarios per category, compared to AR6. Most notably, no scenarios remain in the lowest

warming category (C1). All scenarios previously classified in this category have become outdated and fail the vetting criteria and/or raise major feasibility or sustainability concerns (see Figure 1, panel a, c, e). Many of the scenarios fail the tests since they assume unrealistically rapid scale-up of carbon capture and storage (CCS, BECCS, and DACCS) or nuclear power. Often this is accompanied by rapid phase-down of coal between 2020 and 2025, which did not take place in the real world ²⁷.

Recent policy developments and observed emissions trends have thus followed a markedly weaker trajectory than these earlier (C1) scenarios, with global emissions continuing to rise rather than decline. As a result, pathways that would have limited peak warming to around 1.5 °C are thus no longer feasible under realistic assumptions or do not pass the vetting and feasibility criteria (see Supplementary Information, Table SI.1 and Table SI.2).

The lowest feasible warming pathways in the updated ensemble exhibit a peak warming of around 1.7 °C (50% likelihood). Many of these pathways still manage to reduce warming back to 1.5 °C by the end of the century without raising major feasibility, plausibility, or sustainability concerns (see Figure 1, panel c). Thus, we conclude that, while limiting peak warming to around 1.5 °C with 50% likelihood has become out of reach, returning warming to 1.5 °C later in the century remains feasible.

Reflecting these changes, we introduce an updated warming categorization compared to AR6 (Table 1). The primary dimension of the revised categorization is the level of peak global warming over the course of the century. In addition, subcategories distinguish between scenarios that manage to bring down warming significantly after the peak (overshoot scenarios) and those that don't. As in AR6, we retain eight categories: GW1 corresponds to the former C1 category , with a peak warming of about 1.6 °C; GW2 represents the lowest attainable pathways in the recent literature, with a peak warming of 1.7 °C; and GW3 corresponds to pathways with a peak warming that will likely remain below 2 °C. Subcategories distinguish scenarios that return warming to below 1.5 °C by the end of the century (subcategory a) from those that do not (subcategory b).

Table 1: *Scenario categorization according to projected global warming. Primary categories reflect peak warming (PW), with sub-categories distinguishing scenarios that return to 1.5 °C this century from those that do not. Subcategories exist only for GW2 and GW3, since for the other categories (GW4-GW8) there are no scenarios that return to 1.5 °C by 2100. Further classification by net-zero emissions and late-century temperature dynamics is provided in the Supplementary Information section 2.*

Main Category label	Sub-Category label	Peak warming (PW)	Warming at the end of the century (EoCW)	Similar category in the IPCC AR6 (C1-C8)
GW0 Below 1.5°C with no overshoot		$PW_{50} < 1.5^{\circ}\text{C}$	$EoCW_{50} < 1.5^{\circ}\text{C}$	C0
GW1 1.5°C with limited overshoot		$PW_{50} < 1.6^{\circ}\text{C}$	$EoCW_{50} < 1.5^{\circ}\text{C}$	C1
GW2 Below 1.7°C	GW2a Below 1.7°C returning to 1.5°C	$PW_{50} < 1.7^{\circ}\text{C}$	$EoCW_{50} < 1.5^{\circ}\text{C}$	lower part C2
	GW2b Below 1.7°C without returning to 1.5°C	$PW_{50} < 1.7^{\circ}\text{C}$	$EoCW_{50} < 1.7^{\circ}\text{C}$	N/A
GW3 Likely below 2°C	GW3a Likely below 2°C returning to 1.5°C	$PW_{67} < 2^{\circ}\text{C}$	$EoCW_{50} < 1.5^{\circ}\text{C}$	Upper part C2
	GW3b Likely below 2°C without returning to 1.5°C	$PW_{67} < 2^{\circ}\text{C}$	$EoCW_{67} < 2^{\circ}\text{C}$	C3
GW4 Below 2°C		$PW_{50} < 2^{\circ}\text{C}$	$EoCW_{50} < 2^{\circ}\text{C}$	C4
GW4 Below 2.5°C		$PW_{50} < 2.5^{\circ}\text{C}$	$EoCW_{50} < 2.5^{\circ}\text{C}$	C5
GW6 Below 3°C		$PW_{50} < 3^{\circ}\text{C}$	$EoCW_{50} < 3^{\circ}\text{C}$	C6
GW7 Below 3.5°C		$PW_{50} < 3.5^{\circ}\text{C}$	$EoCW_{50} < 3.5^{\circ}\text{C}$	Lower part of C7
GW8 Above 3.5°C		$PW_{50} \geq 3.5^{\circ}\text{C}$	$EoCW_{50} \geq 3.5^{\circ}\text{C}$	Upper part of C7+C8

Updated global emissions benchmarks

We now focus on emissions benchmarks that are relevant to the goals of the Paris Agreement and that would help policy makers set near-term targets. The scenarios with peak warming *well below* 2 °C, summarized by the categories GW2 and GW3, are here of particular relevance.

Key benchmarks include near-term global GHG emissions reductions and the timing of achieving net-zero CO₂ and net-zero GHG emissions. Following recent methodological recommendations^{28,29}, we do not apply any outlier exclusions based on statistical sampling of the scenario set as done, e.g., in the IPCC assessments. Instead, we derive benchmarks from scenarios that meet feasibility and sustainability criteria and do not exceed thresholds associated with major concern in these dimensions.

We find that global GHG emissions reductions of around 60% (57 – 63%) by 2035 relative to 2019, followed by further reductions to 90% (84 – 94%) by 2050, are consistent with limiting peak warming to the lowest possible level of <1.7 °C. CO₂ emissions from fossil fuels and industry follow a comparable reduction trajectory. While pathways with less stringent near-term emissions reductions exist within this warming category, they are associated with substantial feasibility or sustainability concerns and are therefore excluded from the benchmark calculation. These concerns primarily apply to the highly ambitious pathways mentioned further above, and which were published over the last decade assuming a quick phase-out of coal power generation alongside substantial investment in CCS and nuclear power – developments that have not materialized in the recent years.

The new benchmarks for 2035 are broadly comparable to the ambitious level derived previously in the AR6 Synthesis report and Summary for Policy Makers ⁴. Due to the weak policy signals of the recent years and the resulting high levels of cumulative emissions between 2020 and 2025, however, peak warming levels associated with these emissions reductions are now at around 1.7 °C and thus about 0.1 °C higher than in AR6. This demonstrates that the insufficient policy implementation of the recent years had a sustained effect on peak warming, which can no longer be compensated by increasingly forceful reductions over coming decades.

Likely limiting peak warming to around 2 °C requires less stringent near-term reductions, on the order of 13% – 53% by 2035, and 56 – 82% by 2050.

Timing of net-zero emissions

The time when global CO₂ emissions reach net zero is critically important, since it paces the efforts to the moment when global warming would reach its turning point and temperatures start to decline again ^{30,31}. For limiting warming to 1.5 °C with the lowest possible overshoot (category GW2), net-zero CO₂ is achieved around 2050 (2047 and 2059).

In the GW3 pathways, net-zero CO₂ emissions can be achieved somewhat later. How much later depends greatly on whether warming is brought back this century to 1.5 °C or not. This question is also highly policy relevant, given that the Paris Agreement is calling to pursue efforts to limit warming to 1.5 °C, and since recently also the International Court of Justice has identified 1.5 °C as the 'primary temperature objective' in its Advisory Opinion on the obligations of states in respect of climate change ³². We thus compute benchmarks for scenarios that manage to bring back warming to 1.5 °C before the end of the century (GW3a) and those that keep warming at relatively higher levels and do not manage to reach 1.5 °C (GW3b) by 2100. In the former pathways that return warming to 1.5 °C (after an overshoot to likely 2 °C), net-zero CO₂ is already reached between 2060–2064. In contrast, GW3b pathways that stabilize warming likely around 2 °C (without subsequent draw-down to 1.5 °C) delay net-zero CO₂ emissions until late in the century (See Figure 2).

Our scenario assessment indicates that “Paris-consistent scenarios” that manage to bring back temperatures to 1.5 °C and keep warming to *likely* below 2 °C (GW2a and GW3a) would have to reach net zero CO₂ emissions between 2047 and 2064. This leaves only 21–38 years for the transformation of the global economy.

In most scenarios, net zero GHG emissions are reached about 10 years after the time of net zero CO₂ (see Figure 4a, and in the Supplementary Information Table SI.4 and Table SI.5).

Transitioning away from fossil fuels

A rapid decline in fossil fuel use is a defining characteristic across all GW2 and GW3 pathways.

In GW2 pathways, global coal use declines sharply by 66–88% to 2035, and 74–99% by 2050. Oil use peaks between now and 2030 in the all GW2 scenarios and declines thereafter by 6–36% in 2035 and 57–70% in 2050. For natural gas the speed of phasing down consumption is similar, reaching reduction levels of 18–58% by 2035 and 40–90% by 2050.

These ranges reflect variation across internally consistent model pathways within the category. Importantly, they should not be interpreted as independent upper limits that can be combined across fuels. The upper bound for one fuel does not imply that similarly lenient reductions in other fuels would remain consistent with the same warming outcome. Rather, the ranges describe alternative mitigation strategies that balance reductions across sectors. Pathways with slower reductions in one fossil fuel require correspondingly stronger reductions in others, or greater mitigation effort in non-energy sectors such as land use, industry, or carbon dioxide removal. For example, scenarios with limited reductions in oil use by 2035 generally compensate through faster coal phase-out, stronger electrification, accelerated deployment of zero-carbon technologies, or higher net-negative emissions later in the century. The reported ranges therefore illustrate the diversity of feasible transformation pathways, not minimum performance standards for individual fuels or actors. Any specific benchmark must be understood within the context of a complete, economy-wide mitigation strategy consistent with the stated temperature goal. For example, the higher bound of the fossil fuel range, is generally conditional on successful upscaling of CCS (see Supplementary Information Figure SI.1, and Figure 2).

GW3 pathways allow for a slower transition, particularly for oil and gas, but still require substantial reductions in fossil fuel consumption over the coming decades. In all Paris-consistent pathways, the transition away from unabated fossil fuel use is a central and unavoidable component of the mitigation strategy.

Scaling up solar and wind

The rapid scale-up of renewable energy is a central pillar of all pathways that limit peak warming to well below 2 °C. Across both GW2 and GW3 categories, non-biomass renewable - primarily wind and solar - continue to expand at very high rates over the coming decades, building on the already rapid growth observed in the past decade.

In pathways limiting peak warming to around 1.7 °C (GW2), global deployment of wind and solar increases by a factor of approximately 2.0-4.9 by 2035 relative to 2019. By mid-century, renewable energy supply reaches levels around 5.5 to more than 9 times higher than in 2019. These expansion rates are required to compensate for the rapid phase-out of fossil fuels while meeting growing global energy demand.

Similar near-term scale-up rates are observed in GW3 pathways that *likely* limit peak warming to around 2 °C. While these pathways allow for somewhat higher residual fossil fuel use by midcentury, they nevertheless require comparably rapid deployment of renewable energy infrastructure, underscoring that large-scale renewable expansion is unavoidable across all Paris-consistent scenarios (Figure 2).

By 2050, energy supply by wind and solar reaches approximately 133–254 EJ of primary energy across GW2 and GW3 pathways, corresponding to around 30–51% of total global primary energy use. Notably, these build-out rates exceed those assumed in many scenarios assessed in the IPCC AR6, reflecting both recent real-world acceleration in renewable deployment and the reduced scope for delaying mitigation action following weaker-than-expected emissions reductions in the early 2020s.

Contribution of CDR

Achieving net-zero CO₂ emissions in global mitigation pathways requires not only deep emissions reductions but also the deployment of CDR to counterbalance residual emissions from sectors with limited abatement potential. These residual emissions arise primarily from transport, industry, and, in some scenarios, parts of the buildings sector (Figure 4b).

Across the scenario ensemble, net-negative CO₂ emissions are generated mainly through a combination of land-based removals in the forest and land-use sector and engineered CDR options associated with the energy system. Some scenarios additionally deploy emerging CDR approaches, such as direct air carbon capture, (DAC) biochar, enhanced weathering (EW), or ocean-based methods, although these CDR options are typically reported less consistently across the scenario variables.

Scenarios that comply with the feasibility and sustainability criteria rely substantially less on CDR than those that raise major concerns. In the former pathways, net-negative CO₂ emissions generally reach levels of around 2–8 GtCO₂ per year, sufficient to offset remaining positive emissions without requiring implausibly large-scale deployment of removal technologies (Figure 4b; see the SI for the assumed CDR sustainability criteria).

Cumulative net-negative CO₂ emissions over the course of the century vary with the degree of temperature overshoot. In GW2a pathways that peak around 1.7 °C and return warming to 1.5 °C before the end of the century, cumulative net-negative emissions amount to approximately 185–364 GtCO₂ between 2020 and 2100. In GW3a pathways with higher peak warming and larger overshoot, cumulative net-negative emissions increase substantially, reaching around 444–550 GtCO₂ over the same period.

These results quantify a relationship well established in the literature - that delaying near-term emissions reductions increases long-term reliance on carbon removal and associated feasibility, sustainability, and governance challenges^{19,33}. Importantly, benchmarks that prioritize rapid near-term emissions reductions (Figure 2) allow pathways to remain toward the lower end of the carbon dioxide removal (CDR) benchmark range.

Socioeconomic development

Although the scenarios span a wide quantitative range of socioeconomic outcomes (Figure 3), they rely on a relatively narrow set of underlying narratives. Most pathways are broadly aligned with SSP1 or SSP2, meaning that diversity in numerical assumptions does not translate into comparable diversity in storylines. This reflects, first, that many scenarios adopt SSP2 “middle-of-the-road” assumptions, which

are widely perceived as the most plausible representation of near-term socioeconomic expectations, and second, that the most stringent emissions pathways are generally not feasible under storylines characterized by high mitigation challenges, such as SSP3 or SSP5. These storylines are thus absent from the low-warming scenario space ³⁴.

Across the scenario ensemble, socioeconomic development is characterized by steadily rising affluence and reduced income inequality over time (Figure 3).

In almost all assessed pathways, global average income reaches levels exceeding today's average income in the European Union over the course of the century, and in most scenarios reaches levels comparable to income in the United States (Figure 3b). At the same time, income inequality declines markedly (Figure 3c). The income ratio between the Global North and the Global South falls from more than a factor of three today to a median of around 1.5, with many scenarios showing even stronger convergence. While none assumes full income convergence, sustained improvements in global equity are a consistent feature.

Discussion

The SCI scenario collection and evaluation process (see Methods) responds to the need for an open, community-driven, and continuously updated scenario collection process ²⁹. It is designed to better support scenario-based assessments by enabling early, “live” access to scenario data, transparent and reproducible vetting, and broader community participation.

The collected scenarios represent an “ensemble of opportunity” ³⁵, reflecting emissions pathways developed by the scientific community under current knowledge, modelling capabilities, and policy contexts. It does not constitute a systematic exploration of all possible futures, but rather a synthesis of available and policy-relevant scenarios.

Previous assessments have relied on statistical summaries of large ensembles ^{2,35,36} sometimes obscuring feasibility and sustainability concerns. By contrast, our approach explicitly evaluates these concerns and derives benchmarks from a curated subset of scenarios that meet minimum feasibility and sustainability criteria.

The resulting benchmarks should be understood as dynamic and subject to change over time, as they depend on real-world developments such as climate policy ambition, technological progress, and economic conditions. As these factors evolve, so too does the feasible and sustainable scenario space from which benchmarks are derived. Additional dimensions of sustainability and feasibility can therefore be incorporated in future updates of the benchmarks. To support this evolution, the scenario ensemble is designed for regular updating, with an annual update cycle planned to enable the progressive refinement of benchmarks over time and to ensure continued policy relevance.

A limitation of the current assessment relates to the reporting of CDR and CCS activities in emissions scenarios. Across much of the ensemble, direct reporting of CDR and CCS by sector, source, and technology remains incomplete. As a result, benchmarks related to net-negative CO₂ emissions focus on aggregate amounts of CO₂ removal rather than on the detailed sectoral composition of CDR options. More consistent and granular reporting of CDR and CCS in future scenario submissions would substantially improve the ability to derive more disaggregated benchmarks.

A further challenge emerges at the low end of the emissions range. The number of remaining scenarios that meet sustainability, feasibility, and plausibility criteria in very stringent mitigation categories is small and is characterized by limited diversity of modelling frameworks (Figure 1). This constrains the robustness of conclusions regarding transition characteristics under the most ambitious pathways. To address this gap, scenario developers are encouraged to undertake inclusive and coordinated model comparison exercises that explicitly target this remaining low-emissions space (e.g. Pelz et al., 2025).

Finally, benchmark results are sensitive to the chosen thresholds for feasibility and sustainability concerns. To address this, the accompanying Scenario Compass interface (<https://scenariocompass.org/>) allows users to explore how benchmarks change when thresholds are adjusted, or additional criteria are introduced, supporting transparent and user-specific analyses.

Methods

Moving forward with the SCI platform, a novel “live” scenario collection and curation approach is designed to provide timely access to the most up-to-date ensemble of global emissions scenarios while ensuring transparency, consistency, and scientific robustness. The framework consists of a sandbox environment (Supplementary Information Figure SI.3) that serves as the back-end for modelling teams and the Scenario Compass as a publicly accessible front-end for users. Together, these components enable a high degree of inclusiveness for scenario developers and a high level of transparency for users interested in curated, policy-relevant emissions pathways.

In contrast to earlier approaches that focused on compiling scenario ensembles at specific points in time⁷, the SCI community effort follows a continuous collection process. New scenarios are made available to users in near-real time once they are submitted and released by the modelling teams, allowing early “live” access to the evolving scenario landscape.

An important feature of this approach is the regular re-evaluation of scenarios. Each year, all scenarios in the database are subjected to a set of basic vetting tests. Scenarios that do not pass these tests are removed from the curated ensemble used for benchmark assessment. For continuity and transparency, such scenarios are not deleted from the database but are instead retained and labelled as *failed vetting*. This allows users to conduct their own analyses, compare scenario vintages, and assess how conclusions depend on scenario inclusion choices.

Once an emissions scenario is submitted, it initially enters the sandbox environment. The sandbox provides modelling teams with access to a suite of standardized diagnostics and processing tools, including emissions harmonization, variable infilling, and the assessment of resulting climate projections using methodologies consistent with those applied in the IPCC Sixth Assessment Report ³⁸. This allows modelling teams to evaluate how their scenarios compare to others in the ensemble and to identify potential issues early in the submission process.

The sandbox also enables the application of diagnostic tests to assess key pathway characteristics, including basic vetting, feasibility tests, and sustainability checks. Access to the sandbox is restricted to modelling teams. Scenarios that are submitted by the modelling teams for public use and that meet minimum documentation requirements are made available through the Scenario Compass, which serves as the public front-end of the database (see Supplementary Information, Figure SI.3). The Scenario Compass thus provides timely access to all scenarios intended for public consumption.

The vetting tests focus on whether scenarios adequately represent the current global system and whether their recent trends remain consistent with observed historical developments. In particular, scenarios are assessed for consistency with current emissions levels and recent energy- and land-use trends. A substantial number of scenarios assessed in earlier collections fail these criteria, primarily because they assumed rapid strengthening of climate policies that did not materialize in the real world. For vetting variables and thresholds, see Supplementary Material Table SI.1.

The feasibility and plausibility tests assess whether near-term deployment rates of key technologies fall within empirically grounded bounds of what can reasonably be achieved. These tests focus primarily on technologies that play a central role in mitigation pathways, including renewable energy, carbon capture and storage, and other emerging low-carbon options. Thresholds (see Supplementary Material Table SI.2) are defined based on historical deployment rates, observed diffusion patterns of successful technologies, and near-term project pipelines.

The sustainability tests focus on three main dimensions: the sustainable use of bioenergy, implications for food security, and the long-term sustainability of cumulative CO₂ storage volumes. All sustainability indicators are evaluated at the global level using scenario-reported values and derived metrics. Scenarios that exceed major concern thresholds in any of these dimensions are excluded from the benchmark-relevant ensemble.

For the categorization of scenarios into global warming levels, we apply a consistent climate assessment framework. Emissions pathways are, after quality control against recent emissions ³⁹, harmonized to historical emissions, infilled where necessary, and translated into temperature outcomes using the MAGICC climate model. The climate assessment workflow is applied as used in the AR6 assessment ⁴⁰ to ensure consistency with established assessment methodologies and allow direct comparison across scenario vintages.

Declarations

Data availability

The scenario ensemble is available via an interactive dashboard and for download at <https://scenariocompass.org>. In addition to this paper, the data should be cited as “Scenario Compass Ensemble Release 2025 v1”, Huppmann et al. (2026), <https://doi.org/10.5281/zenodo.18598251>

Code availability

The Python code and configuration for vetting and feasibility/sustainability criteria as well as the scripts for generating the figures and tables in this manuscript will be released under an MIT license at <https://github.com/iamconsortium/scenariocompass>.

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Author information

Contributions

All authors contributed substantially to the development of the scenario dataset underpinning the SCI platform. K.R., L.C., B.v.R., K.S., and D.H. developed the paper concept, and K.R. wrote the initial draft. K.S. and D.H. performed the scenario analyses. G.L., T.H., D.H., K.S., and P.C.V. conducted the feasibility and sustainability assessment. E.K. and C.S. developed the new global warming categorization. J.K., Z.N., and C.S. conducted the harmonization, infilling and climate assessment. D.H., P.M., and P.H. managed the online database. J.R., G.L, T.H., P.C.V , E.K., L.C., D.H., K.S., B.v.R, H.R.B., E.B., M.D., P.H., P.M., C.S., D.v.V, T.F., K.L., R.S., M.Tavoni,, and S.S.V contributed to the review, revision and drafting of the manuscript. H.R.B., E.B., M.D., D.H. P.H., P.M., Z.N., C.S., and D.v.V. facilitated the scenario collection and contributed to the scenario assessment. J.E., T.F., N.H., K.L., S.M., P.P., S.R., R.S., M.Tavoni, M.Thomson, and S.S.V. advised on data collection and scenario assessment and contributed to the strategic oversight, organization, and operation of the initiative. K.R. and L.C. co-chaired the SCI. All authors contributed to the review of the manuscript and the scenarios collection.

Ethical declarations

Competing interests

The authors declare no competing interests.

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Figures

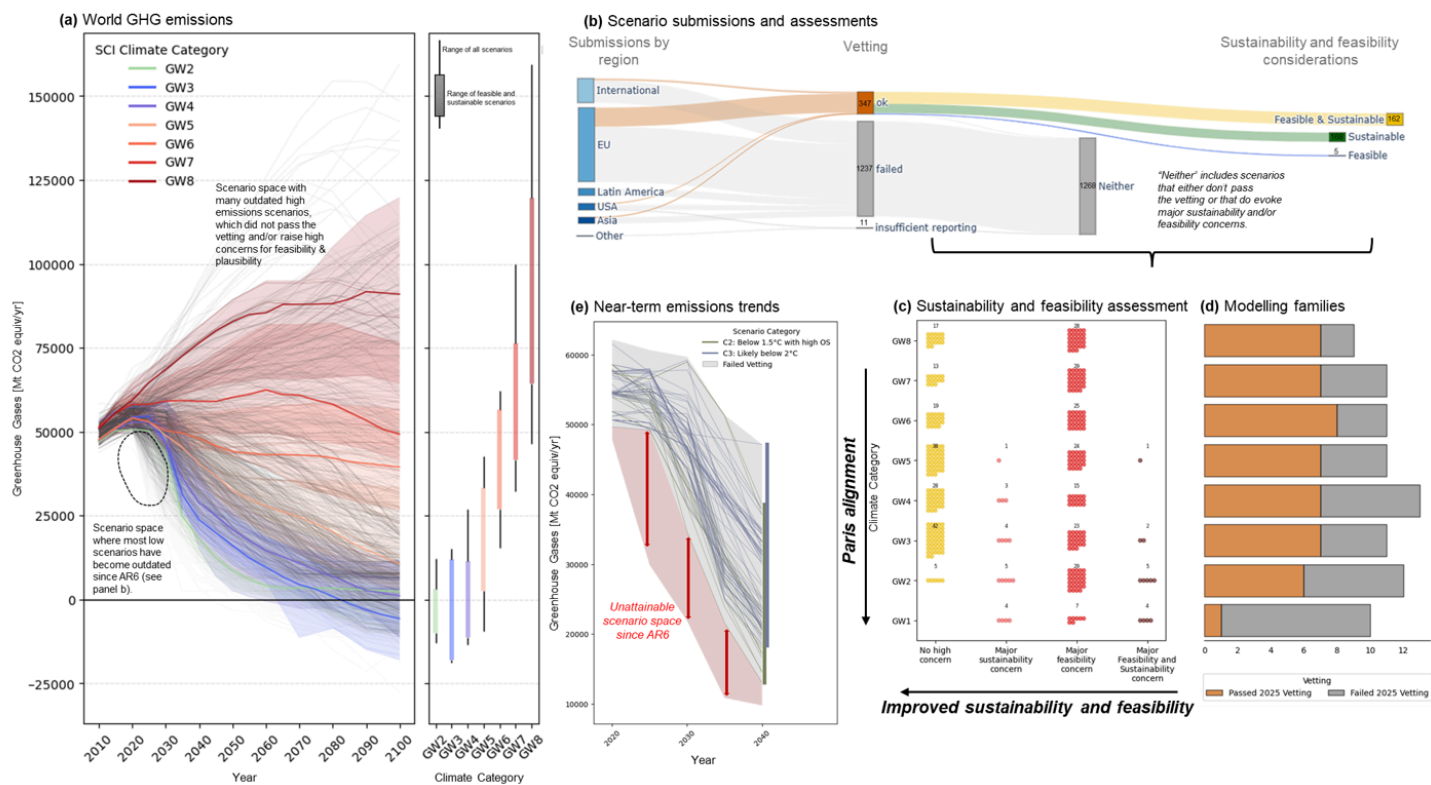


Figure 1

Scenario collection, vetting, and resulting emissions trajectories. **Panel (a)** shows the global development of GHG emissions according to eight Global Warming categories (GW1–GW8). Colored ranges indicate the feasible and sustainable scenario space without any **major** concerns for these dimensions. **Panel (b)** presents the Sankey diagram for submitted scenarios to the SCI platform, showing the submissions per region; the results from the vetting (the share of scenarios that passed and those that failed the vetting); and the fraction of scenarios that raise no “**major**” sustainability and feasibility concerns. **Panel (c)** shows the number of scenarios (colored dots) that pass the sustainability and feasibility tests for each Global Warming category. Sustainability tests do consider transition risks, but do not include impacts of climate change. No sustainable and feasible scenario is left from the AR6 ensemble in the GW1 category (see lower left corner). **Panel (d)** depicts the number of model results available within each warming category. **Panel (e)** shows the near-term GHG emissions trends with red arrows indicating the scenario space that has gotten out of reach since AR6.

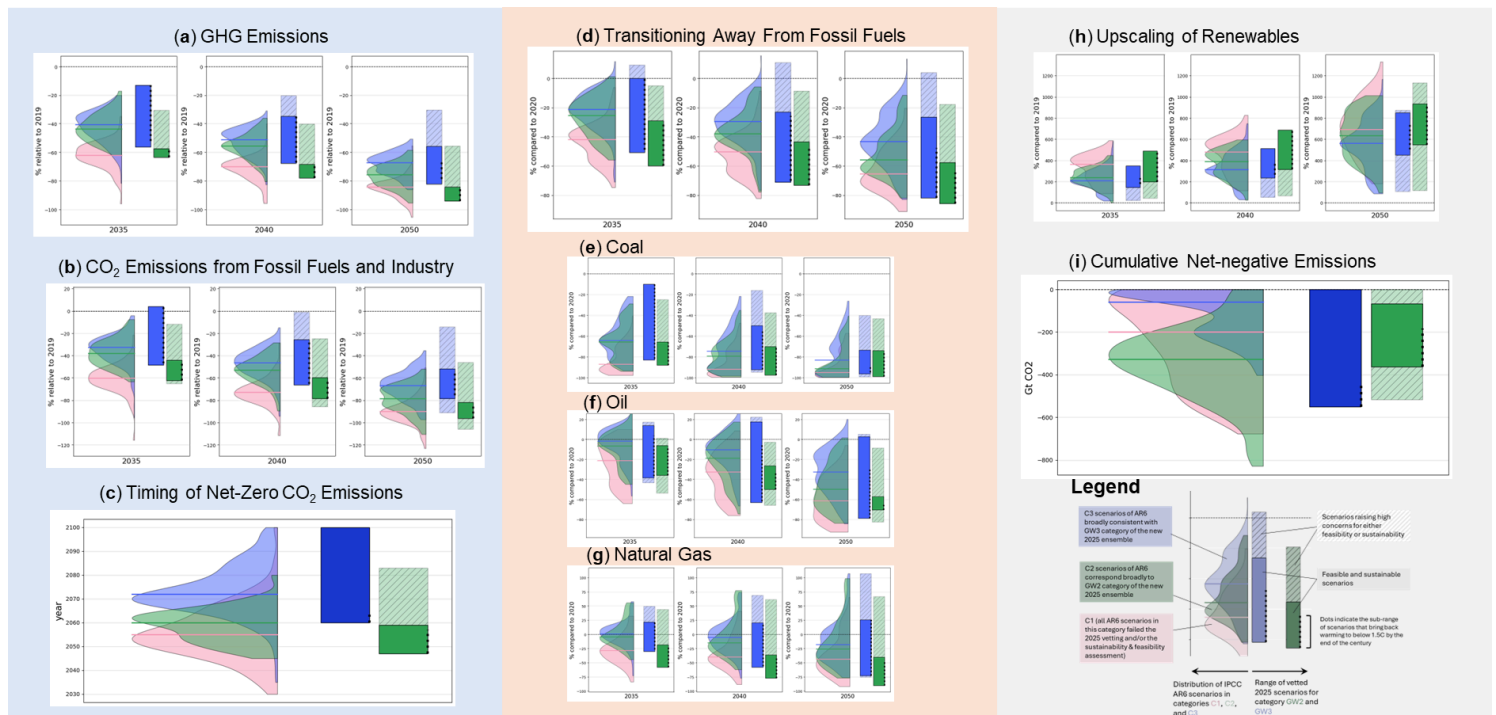


Figure 2

Scenario characteristics and benchmarks for the years 2035, 2040, and 2050. The scenario distribution from the IPCC AR6 is compared to the sustainable and feasible benchmark ranges of the new 2025 ensemble. For benchmarks for the year 2030 see the Supplementary Information, Figure SI.2.

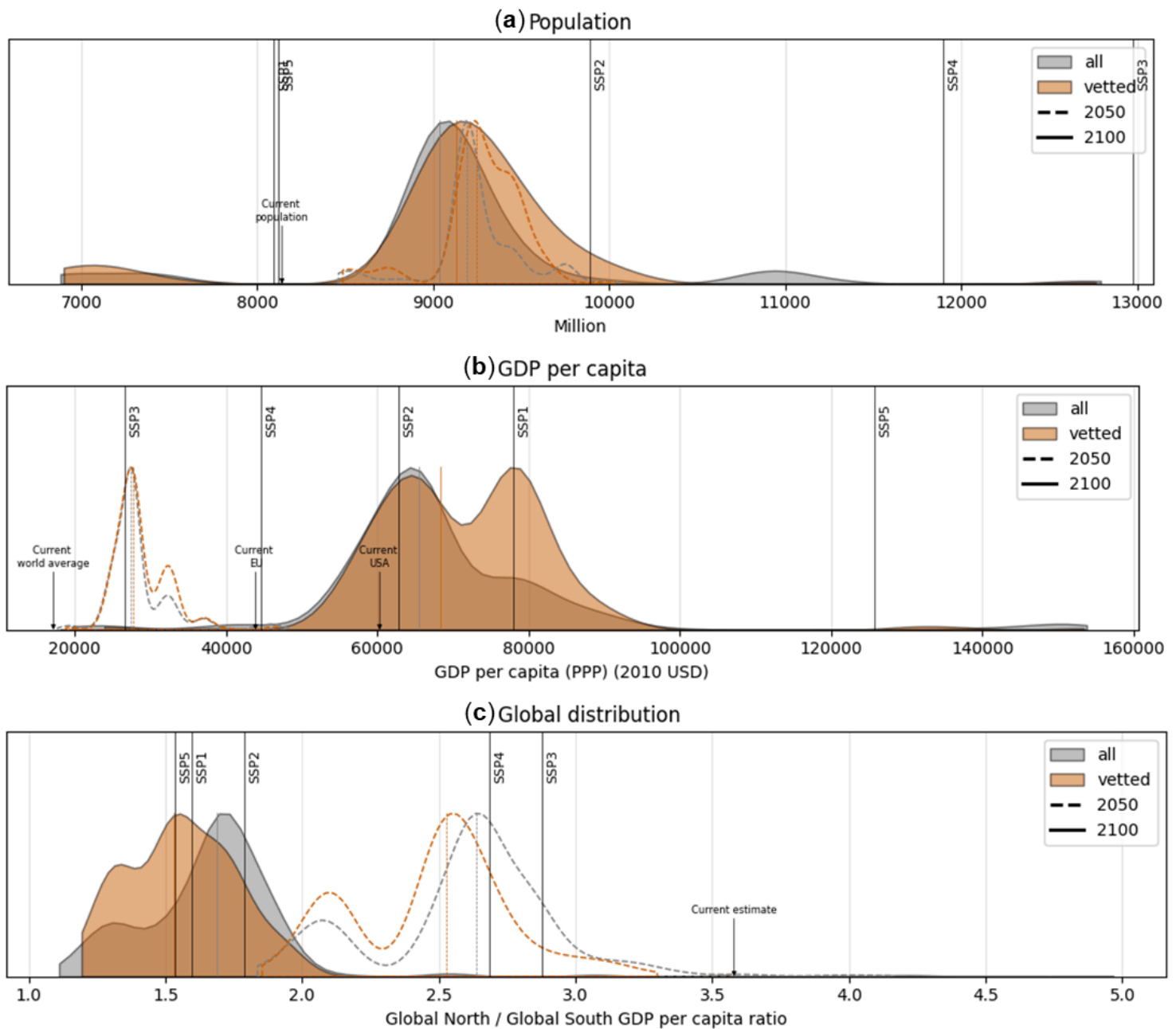


Figure 3

Socioeconomic assumptions for population (panel a), GDP per capita (panel b), and income ratio between the Global North and the Global South (panel c). The distribution of the scenarios of the new 2025 ensemble are compared to the relative position of the five different Shared Socioeconomic Pathways (SSPs). Dashed lines denote results from 2050 and straight lines for 2100. (source of the new update SSP data: <https://ssp.apps.ece.iiasa.ac.at/>)

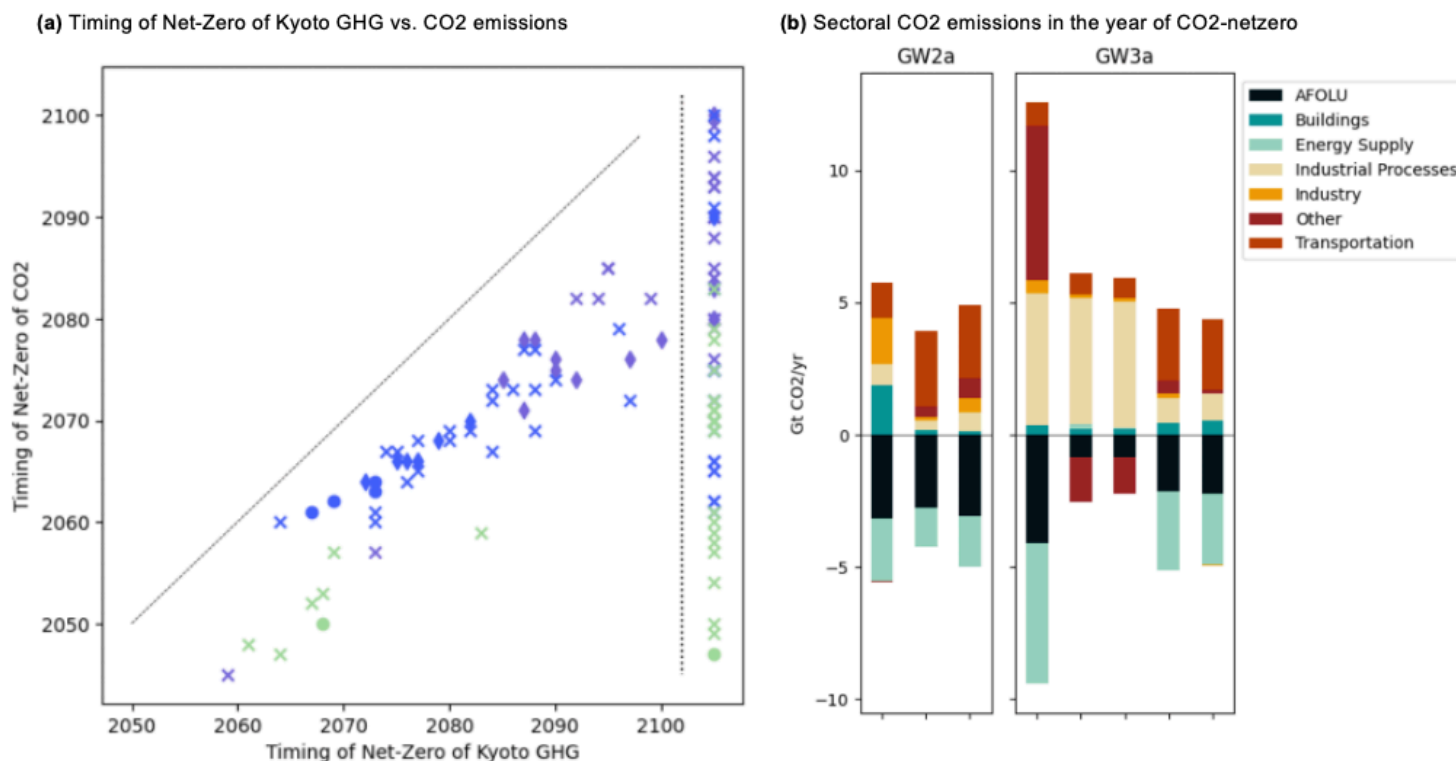


Figure 4

Net-zero timing (panel a), and net-zero emission systems at the time of net-zero CO₂ emissions (panel b). Panel (b) focuses on the eight GW2 and GW3 scenarios that manage – after overshoot – to reach 1.5 °C (50% chance) by the end of the century. The colored bars indicate the net emissions across sectors that remain emissions sources vs. sectors that need to create negative emissions to reach net-zero emissions.

Supplementary Files

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- [ContributingModellersandScenarioDevelopersconsortiumlist.xlsx](#)
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